A different fauna?: captures of vertebrates in a pipeline trench, compared with conventional survey techniques; and a consideration of mortality patterns in a pipeline trench

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ABSTRACT

We sampled the vertebrate fauna caught in a pipeline trench near Daly Waters, Northern Territory in the mid Dry season of 1999, and compared the species composition with that of a standardised quadrat-based survey protocol (using pitfall traps, Elliott traps and nocturnal and diurnal active searches). The proportion of records of snakes, pygopodids, frogs, two dragon species, the gecko *Diplodactylus ciliaris* and the rodent *Pseudomys delicatulus* was markedly greater in the pipeline than in the quadrat-based survey; this disparity was also evident in a pronounced size difference in the reptile species composition of the two techniques. The comparison demonstrates that the standard survey protocol has substantial biases against some species and groups of species and that additional sampling effort or specific new trapping techniques may be required for these taxa.

The species composition of captures in this pipeline study differed substantially from the results from a larger section of this pipeline route constructed in 1994, possibly due to differences in season, habitats spanned, construction procedure or differences between years in climate. Mortality of animals recorded in this pipeline study was 11%, substantially less than that recorded in other pipeline studies. We suggest operational procedures to minimise wildlife mortality in pipeline construction, including construction during the most benign season; minimising the distance and time the trench is kept open; interrupting the trench with frequent escape ramps; and frequent inspection of trenches for captured wildlife.

Key words: Northern Territory, mammals, reptiles, frogs, sampling, impact

INTRODUCTION

Across Australia, as elsewhere (e.g. Heyer *et al.* 1994), several agencies have attempted to develop standard protocols for wildlife surveys (e.g., McKenzie *et al.* 1991; NPWS/SFNSW 1994; Woinarski 1994; Robinson *et al.* 2000). Such consistency facilitates monitoring and the collation and subsequent comparative analysis of geographically separate data sets and it can also provide a mechanism for accreditation of sampling associated with impact assessment. An adequate protocol should ensure that there is a reasonable probability of detection of the taxa chosen for sampling. This probability clearly varies substantially according to sampling techniques (e.g. Friend 1984; Catling *et al.* 1997; Parris *et al.* 1999).

In the monsoonal tropics of the Northern Territory, a standardised procedure for vertebrate survey has become widely adopted (e.g., Griffiths *et al.* 1997; Woinarski *et al.* 1999a,b,c), although there has been no formal assessment of its biases.

Here, we take an opportunity to compare detection using this standard protocol with a very different sampling technique, incidental captures of vertebrates in a pipeline trench. Wildlife caught has been investigated for several such trenches in Australia, although only one formal publication (Ayers and Wallace 1997) has documented the results.

As wildlife mortality may be substantial in trenches (Ayers and Wallace 1997) and since the construction of such trenches is becoming more widespread in Australia, we also investigated patterns of mortality associated with trenching and suggest ways of minimising this mortality.

METHODS

This study was conducted along part of a pipeline route between Daly Waters and Borroloola (Fig. 1). This 330 km gas pipeline was originally laid in 1994 (Dames & Moore 1994), but a 60 km section had to be re-laid in 1999. The route traverses pastoral lands, with vegetation comprising mostly bloodwood-eucalypt woodland (typically dominated by *Eucalyptus pruinosa* and *Corymbia dichromophloia*) or lancewood *Acacia shirleyi* - bullwaddy *Macropteranthes kekwickii* open forest or tall shrubland.

Trench construction occurred over a seven week period (late May to early July 1999). Typical of this early to mid dry season period, there was effectively no rainfall during the construction period and temperatures were relatively low (mean daily maximum and minimum temperatures in June at Daly Waters are 28.8°C and 13.1°C respectively: Dames and Moore 1994). These conditions tend to depress reptile and, especially, frog activity in this region (Fisher 1999).

Mechanical problems led to some inconsistencies in trenching procedure during this operation. In general, one or two specialised digging machines constructed a vertical sheer-walled trench of 1.1 to 1.5 m depth, extending up to about 5 km per day. Prior to pipe laying, a heavy mechanical leveller was run along the bottom of the trench. Pipe was then placed in the trench, which was then immediately filled in, but the time from the trench opening to the pipe laying varied from several hours to several days, depending upon equipment (mal)function. The trench lay within a broader area of disturbance (Fig. 2), which provided a range of obstacles or disincentives for wildlife to reach the trench. In the months before trench construction a corridor of about 10 m width was cleared (or re-cleared following initial clearance in 1994), an easement (with narrow

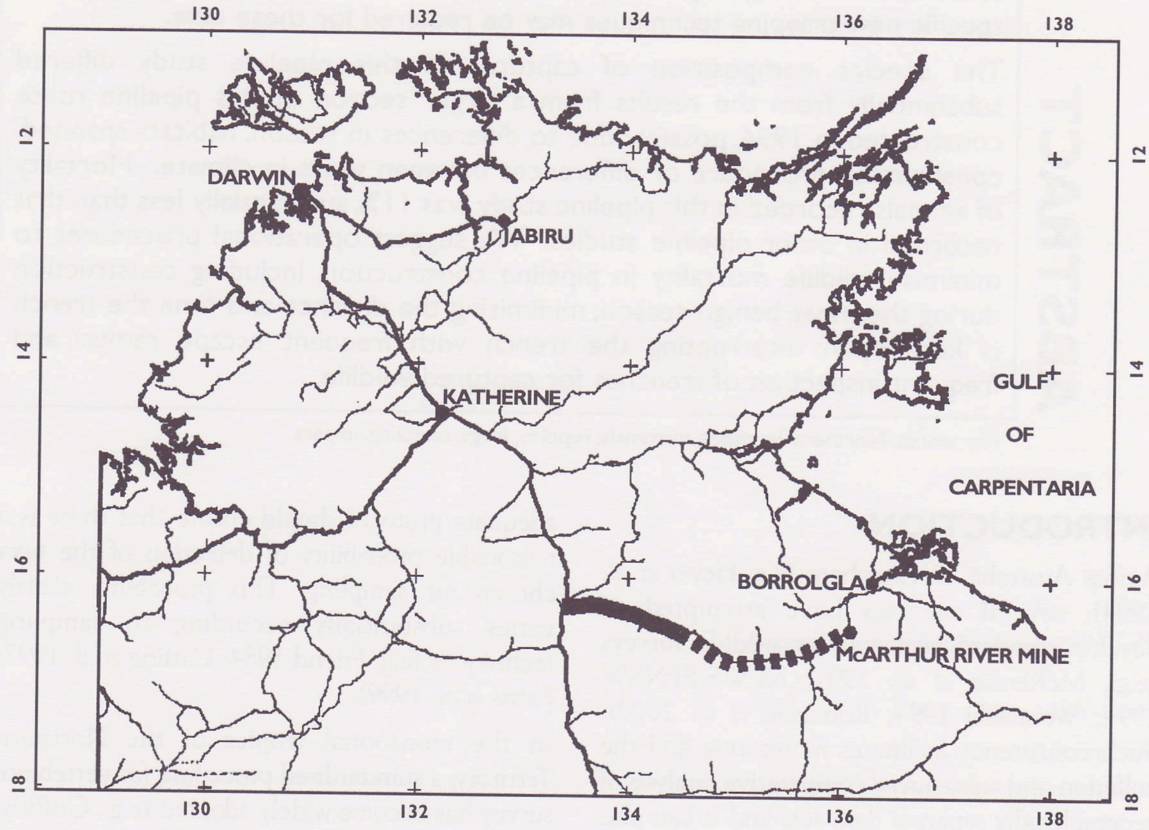

Figure 1. General location of study. Thick black line indicates pipeline route.

dirt track) associated with the previous pipeline was situated on one side of the trench, and a new access track (which during trench placement carried a stream of heavy construction and other vehicles) was located on the other side of the trench. While digging, the trenching machine also placed earth from the trench into a set of parallel continuous mounds immediately alongside the trench.

We searched the trench for wildlife over 12 days in the period from 1-18 June 1999. Searching comprised walking along the entire length of the open trench and removing all vertebrates encountered, with searches undertaken in early morning (from first light) and late afternoon. We recorded the position of each capture (by Global Positioning System and reference to locational markings placed alongside the trench by construction workers) and whether the animal was dead or alive. For each search, we recorded the length of trench open (and searched), the period over which each trench section had been opened, and the period since that section had been last searched. Barring mechanical problems, the trench construction continued throughout day and night, whereas the pipeline laying was continuous throughout the day. Thus, it was difficult to be precise about the actual period during which any particular trench section had been opened. As the trench was (generally) continuous, there was also some imprecision in associating any animal record with a particular period that the trench had been opened, because animals falling into a section of the trench which had been opened for several days may then have moved slong the trench to the most recently constructed sections, or vice-versa.

In addition to animals that we encountered in the trench, we also noted prints of animals moving alongside the trench, and documented some additional records from construction workers reporting captures between our trench searches.

Over the same period as the trench sampling, we also surveyed wildlife using a standard quadrat-based protocol (Woinarski *et al.* 1999a, 1999b). For each 50 m x 50 m quadrat, this comprised a) pitfall trapping, using four pitfall traps (two 20 litre buckets (41 cm deep x 28 cm wide) and two 10 litre buckets (26 cm x 25 cm)), each with 10 m of 30 cm high flywire driftline, b) live mammal traps (20 Elliott traps and four cage traps, baited daily with a peanut butter-honey-oats mixture, and arranged around the perimeter of the quadrat), and c) active searching (three diurnal searches and two spotlight searches, each of 10 min duration). We do not report sampling of birds or bats here. A total of 15 quadrats was sampled, each for a 72 hr period. These were located within 200 m to 5 km of the trench and in a similar range of habitats to those traversed by the trench.

In addition to the detailed study of the 1999 trenching operation, we also here compile and compare capture information from the original laying of the pipeline in 1994. During that construction (which lasted over at least 6 months and extended for several hundred kilometres beyond the 1999 study), the trench was searched on five occasions (24-30 July, 31 August, 26-30 September, 1-5 November and 5-30 November). Search methods then were not as rigorous, and documentation of the results was patchy. Additionally, the 1994 trench was generally markedly less crisp, with less sheer walls, more shallow stretches and far more frequent interruptions (soil ramps which provided escape routes for trapped animals).

We also compare the results from this study with that for two comparable trench sampling studies in western New South Wales (Ayers and Wallace 1997; Faulkner 1999).

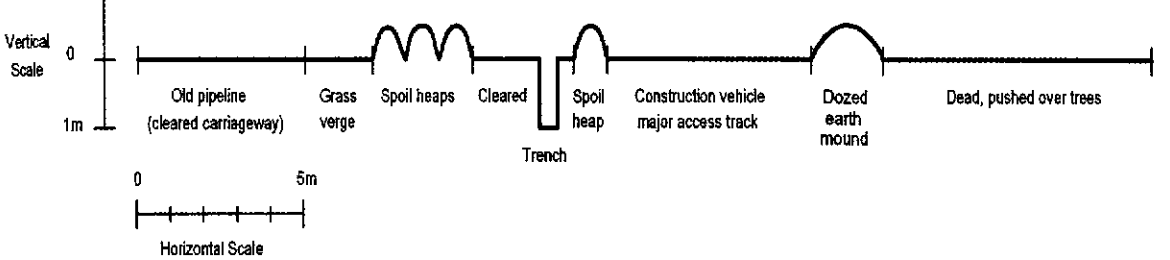

Figure 2. Schematic cross-section of disturbance matrix around trench. Horizontal and vertical axes not at same scale.

Analysis

Tallies for individual species were recorded for each section of the trench searched, where a section is defined as a length searched at a particular time (i.e. date and morning or afternoon), which had been left open for the same time (with a precision of +/- 6 hr), and which had been previously searched at the same time (again, with a precision of +/- 6 hr).

The capture rate of nocturnal animals (no./km of trench searched) was related to the number of nights over which the trench section had been opened and the number of nights since the last search, using generalised linear modelling (Crawley 1993). Comparable analyses were undertaken for diurnal animals, for the number (and proportion) of dead nocturnal animals, and the number (and proportion) of dead diurnal animals. Proportions were arcsine transformed prior to analysis. Analysis included examination of main effects and interaction terms.

The number of captures for each species in the trench was compared with the numbers recorded in quadrat sampling using Spearman rank correlation. A similar analysis was used to examine the relative frequencies of captures in the 1999 and 1994 trench surveys.

The cumulative frequency distribution of size categories for reptiles was compared between trench and quadrat samples using 2-tail Kolmogorov-Smirnov tests (Siegel 1956). We used (average) snout-vent lengths as given in, or derived from, Cogger (1992).

RESULTS

We recorded a total of 349 individual vertebrates of 40 species from the trench, from a total distance of 74.2 km searched (Table 1), with track records of a further five species.

Capture rates of nocturnal animals in the trench were significantly associated with the time since the trench was previously searched (27% of deviance explained, $p<0.001$: Fig. 3), with only 3% of deviance ($p<0.05$) additionally explained by the time the searched section had been opened. No comparable significant relationship was found for diurnal animals, and neither the total number, nor the proportion, of dead animals was significantly related to either the time since the previous search or the period over which the trench section had been open.

Comparison with quadrat results

There was only moderate correspondence ($r_s=0.33$, $p=0.035$) between the species composition of trench captures and those of quadrat captures (Table 1; Fig. 4). Twenty of the 39 species recorded from the trench (excluding the single bird species and those species recorded only from tracks) were not recorded in the quadrat sampling; only one species recorded in quadrats was not also recorded in the trench. The disparity in numbers recorded from trench and quadrats varied among taxonomic groups (Fig. 4). Snakes, pygopodids and frogs were far more common in trench samples than in quadrat samples, whereas skinks, mammals and geckoes were relatively more equitably sampled. For some individual species

Table 1. Comparison of captures of vertebrates in trench in 1999 and results from simultaneous standard survey quadrats, and captures recorded during the construction of the trench in 1994. "t" = recorded by tracks. The no. recorded in quadrats includes both trapped animals (in brackets) and animals located by active search. For trench captures, the number in brackets is the number that were dead when located (=0, unless otherwise indicated)

species	no. recorded in survey quadrats in 1999 (no. trapped)	no. recorded in trench (no. dead) in 1999	in 1994
Amphibians			
Bufo marinus	0	0	8 (1)
Cyclorana australis	0	11 (4)	2
Litoria caerulea	0	0	20 (10)
Reptiles			
Geckos			
unidentified gecko	0	0	9
Diplodactylus ciliaris	1 (1)	18	30 (8)
D. conspicillatus	1 (1)	1	22 (3)
D. stenodactylus	3 (3)	5	2
Gehyra australis	2 (0)	13	3
Heteronotia binoei	4 (2)	40 (1)	4
Oedura rhombifer	6 (3)	1	0

Rhynchoedura ornatus	1 (1)	2	1
Pygopodids			
Delma borea	0	4	5
D. nasuta	0	0	2
D. tincta	0	0	5 (2)
Lialis burtonis	1 (1)	16	57 (10)
Pygopus nigriceps	0	2	54 (17)
Dragons			
Diporiphora bennetti	1 (1)	5	1
D. magna	1 (1)	19 (1)	1
Lophognathus gilberti	2 (1)	22	3
Skinks			
unidentified skink	0	0	5
Carlia amax	0	0	1
C. munda	0	1	0
Ctenotus inornatus	3 (1)	4	7
Ct. pantherinus	4 (0)	2	6 (3)
Ct. pulchellus	0	0	1
Ct. robustus	0	0	4
Ct. schomburgkii	0	0	1
Ct. spaldingi	8 (7)	2	1
Glaphyromorphus isolepis	0	0	3
Menetia maini	8 (8)	3 (1)	0
Morethia storri	4 (2)	0	0
Proablepharus tenuis	0	1	0
Tiliqua multifasciata	0	0	5 (1)
T. scincoides	0	0	8 (4)
Goannas			
Varanus acanthurus	0	0	12
V. gouldii	t	t	0
Snakes			
unidentified snake	0	0	9 (8)
Ramphotyphlops diversus	0	0	1
R. endoterus	0	0	1
R. ligatus	0	1	0
R. sp.	0	2 (1)	1 (1)
Liasis childreni	0	3	3
L. olivaceus	0	1	0
Demansia olivacea	0	0	5
D. papuensis	0	0	1
D. torquata	0	1	4
Furina ornata	0	9	2
Pseudonaja nuchalis	0	1	3
Rhinoplocephalus pallidiceps	0	1	0
Simoselaps incinctus	0	0	3
Suta punctata	2 (2)	3	10 (5)
S. suta	0	0	1
Vermicella multifasciata	0	2	0
Birds			
little button-quail *Turnix velox*		2	0
Mammals			
Tachyglossus aculeatus	0	0	1
Planigale maculata	1 (1)	10	0
Sminthopsis macroura	0	1	0
Lagorchestes conspicillatus	0	3	0
Onychogalea unguirostris	t	t	0
Macropus agilis	t	4	0
Macropus robustus	t	t	0
unidentified rodent	0	0	3
Leggadina lakedownensis	18 (18)	41 (5)	0
Pseudomys delicatulus	0	67 (20)	0
P. nanus	3 (3)	23 (5)	0
Rattus tunneyi	0	1	0
Rattus villosissimus	0	1	0
Felis catus	t	t	0
Canis familiaris	t	t	0

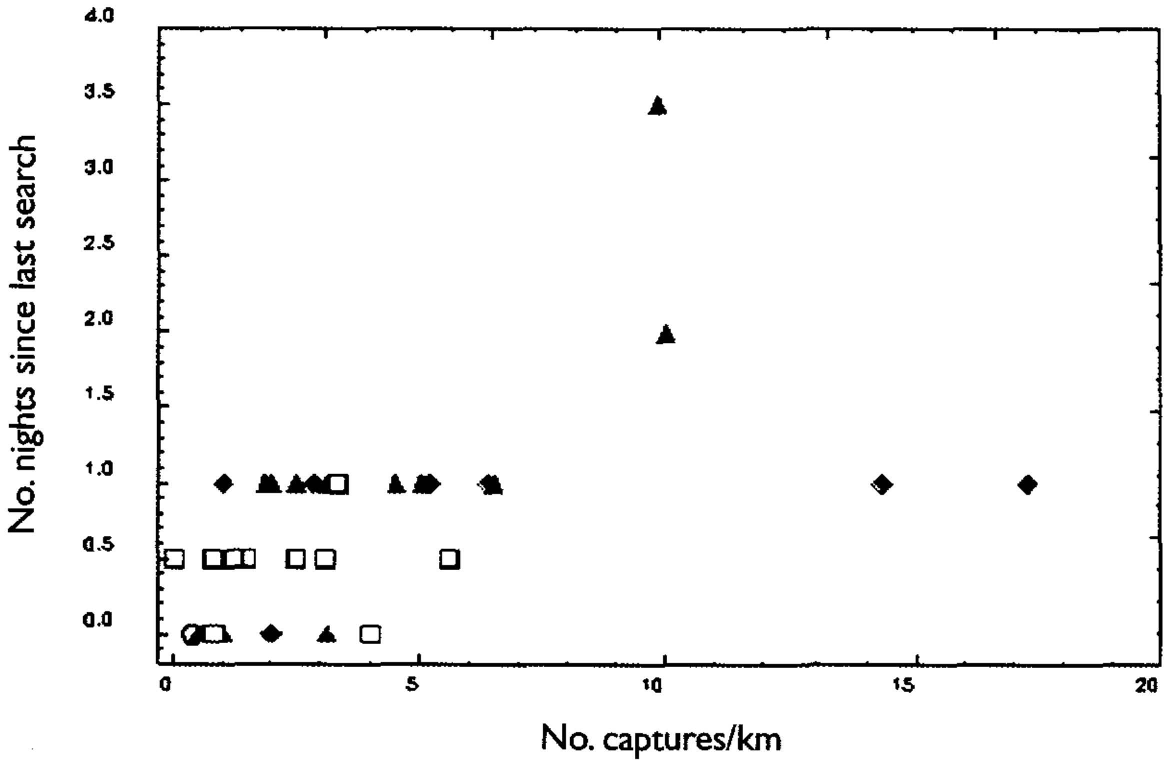

Figure 3. Relationship between numbers of nocturnal animals encountered per km of trench searched and time since the section was last searched. Symbols show trench "age": open circle=trench open for 0 previous nights; open square=trench open for 0.5 previous nights; filled diamond=trench open for 1 previous night; filled triangle=trench open for more than 1 previous night.

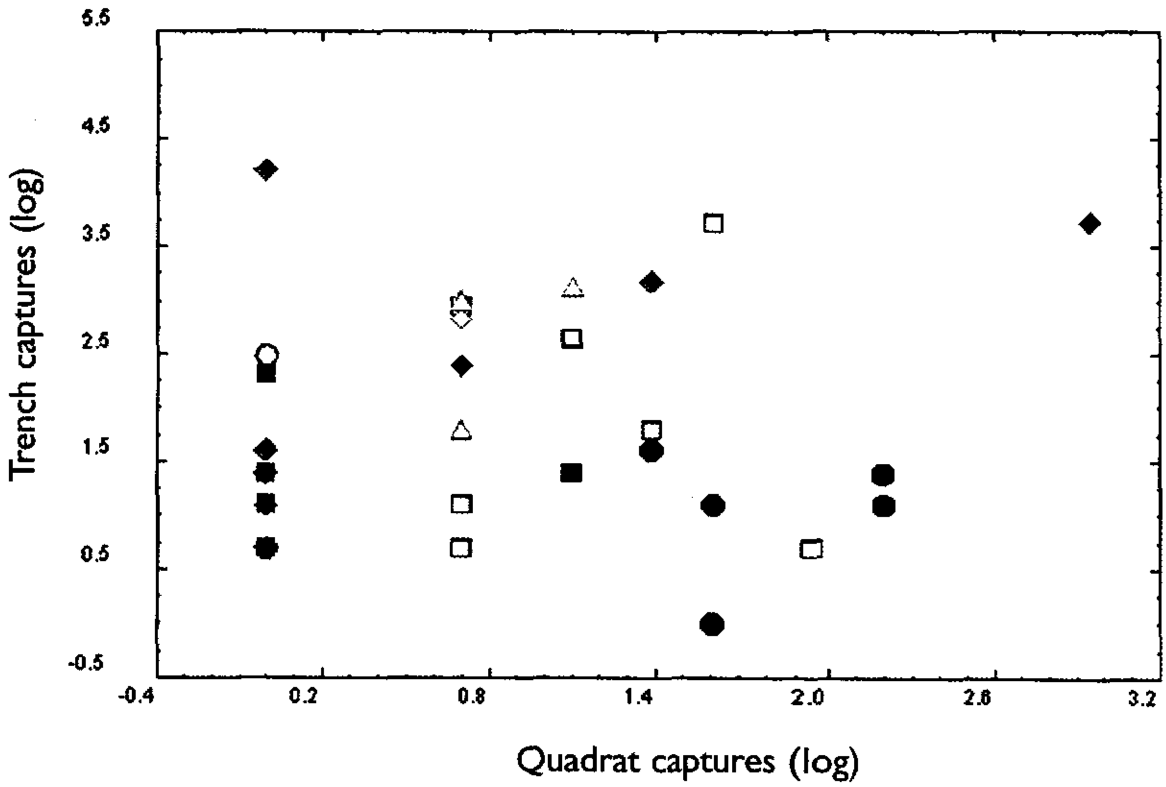

Figure 4. Scattergram showing the number of records in which an individual species was recorded in the trench and corresponding number of records from sampling nearby quadrats. Note that both axes are log-scaled. Key to symbols: open circle=frogs; open square=geckos; open diamond=pygopodids; open triangle=dragons; filled circle=skinks; filled square=snakes; filled diamond=mammals.

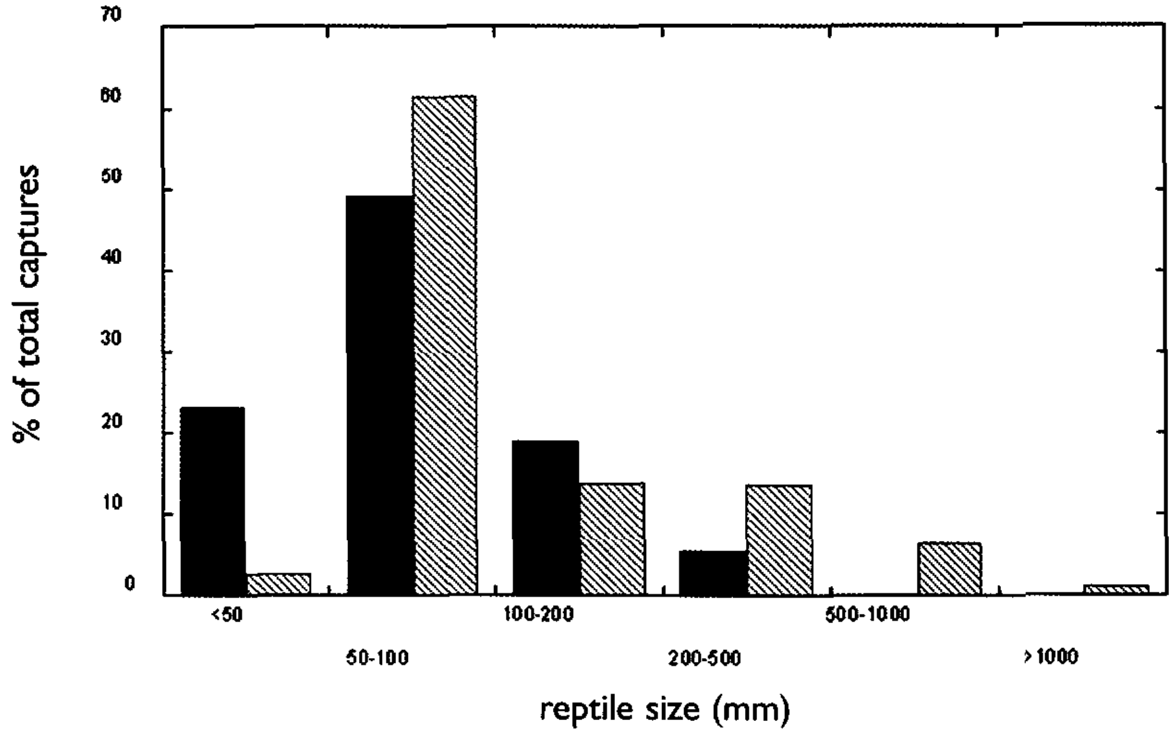

Figure 5. Histograms of size distribution of all reptiles caught in trench (paler bars) and all reptiles recorded from quadrat sampling (dark bars).

(notably the gecko *Diplodactylus ciliaris*, the pygopodid *Lialis burtonis*, the dragons *Diporiphora magna* and *Lophognathus gilberti* and the rodent *Pseudomys delicatulus*), the numbers recorded in the trench was markedly greater than that for quadrat samples.

Considering reptiles only, there was a highly significant ($D=0.204$, $p<0.01$) difference in the size distribution of individuals caught in the trench and those recorded from the quadrats (Fig. 5), with proportionally far more larger reptiles in the trench.

Comparison with other trench studies

The capture rate recorded in this study was greater than that recorded in comparable studies of other pipelines, including that recorded in the previous laying of this pipeline (Table 2). Species richness in this study was generally less than that reported in western New South Wales by Ayers and Wallace (1997), with this difference probably largely due to the greater sampling effort and environmental range sampled in that study. Relatively few frog species were recorded in this study.

Table 2. Comparison of capture rates and mortality between this pipeline and others. Tallies with + indicate that some specimens were not identified to species. Note that the distance searched was not recorded for two sampling periods in 1994. "mort. rate"=% of all animals encountered that were dead.

study	dist. search (km)	no. individs. (no./km)	total no. spp.	mort. rate	no. individuals (no. spp.)			
					frog	reptile	bird	mammal
This study	74.2	349 (4.70)	40	11.1	11 (1)	185 (29)	2 (1)	151 (9)
July 1994	?	20 (?)	10	0	0	20 (10)	0	0
Aug 1994	40	40 (1.00)	16	7.5	1 (1)	39 (15)	0	0
Sept 1994	?	15 (?)	6	26.6	0	15 (6)	0	0
early Nov. 1994	103	198 (1.92)	25+	31.3	25 (2)	169 (21+)	0	4 (2+)
late Nov. 1994	33	52 (1.58)	17	3.8	4 (2)	48 (15)	0	0
Ayers & Wallace	256	680 (2.66)	64	41.8	30 (8)	375 (39)	7 (3)	221 (14)
Faulkner	255	299 (1.17)	27+	52.5	174 (6+)	102 (14+)	5 (3+)	17 (4)

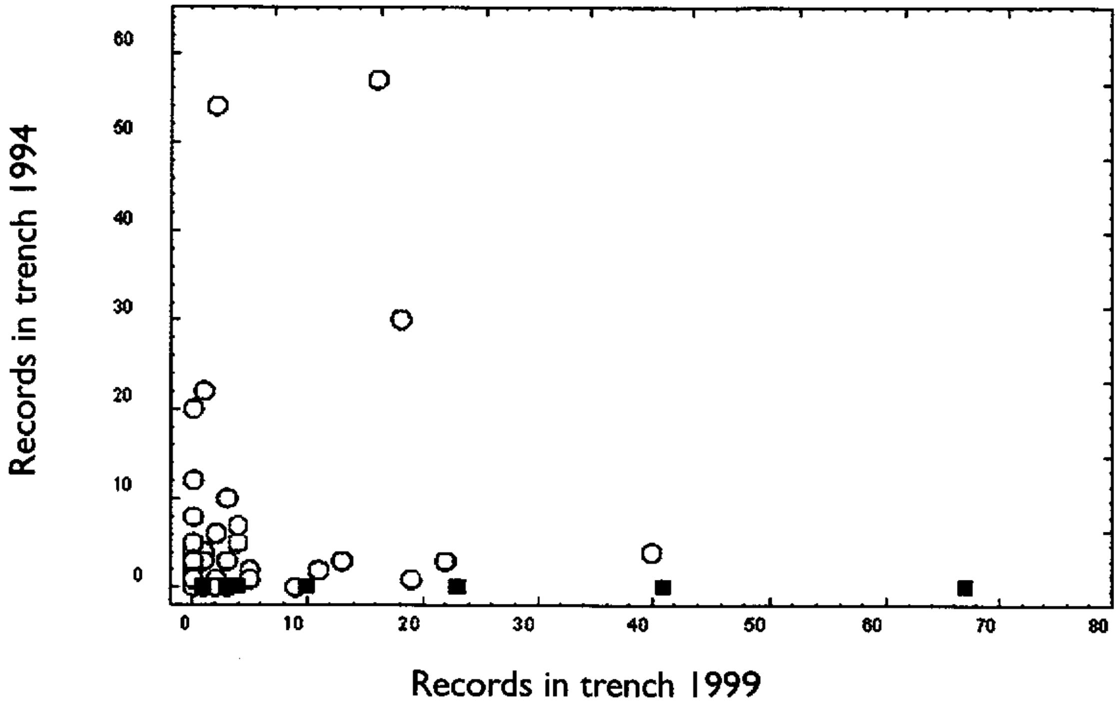

Figure 6. Scattergram showing the number of records in which an individual species was recorded in the trench in 1999 and corresponding number of records from the trench in 1994. Key to symbols: open circle=frogs and reptiles; filled square=mammals.

The mortality rate recorded in this study (11.1%) was substantially less than those from the two previous studies in western New South Wales, and that from the combined sampling of this same pipeline in 1994 (24.9%) (Table 2). Nonetheless, mortality rates for some individual species in this study were substantial (e.g., 30% for *Pseudomys delicatulus*) (Table 1).

Species composition of captures in the trench during this study varied considerably (r_s= -0.14, p>0.05 for all species, and r_s= 0.002, p>0.05 if mammals excluded) from that recorded over a greater length of this pipeline during its initial laying in 1994 (Table 1; Fig. 6). The most marked differences were the absence of rodents and dasyurid mammals, and relatively low abundance of the gecko *Heteronotia binoei*, the dragons *Diporiphora magna* and *Lophognathus gilberti*, and the elapid snake *Furina ornata* in the 1994 sampling, and the much greater reporting rate then of the amphibians *Litoria caerulea* and *Bufo marinus*, the gecko *Diplodactylus conspicillatus*, the pygopodid *Pygopus nigriceps* and the large skinks *Tiliqua* spp. Eighteen species were recorded in 1994 but not 1999, 17 species in 1999 but not 1994, and 22 species in both years.

DISCUSSION

This study has demonstrated that our standard quadrat-based sampling protocol has some substantial biases in species detection and the assessment of the relative abundances of different species. Our quadrat sampling techniques appear to substantially under-represent snakes, pygopodids, frogs and some individual species, most notably the mouse *Pseudomys delicatulus*, the dragons *Diporiphora magna* and *Lophognathus gilberti* and the gecko *Diplodactylus ciliaris*.

The inadequate sampling of these taxa by our standard quadrat protocol appears to relate mostly to behaviour (e.g. *P. delicatulus* appears to be trap-shy for Elliott traps) and size (most of the larger reptiles can climb out of the pitfall traps we used). Conversely, comparison between trench and quadrat results also suggests some biases in trench captures. The most notable of these is the apparent under-representation of the smallest reptiles, which may be due to the substantial matrix of disturbance surrounding the pipeline trench, including a series of spoilheap rows which may provide an effective barrier for smaller reptiles.

The low detectability of some of these species by our standard quadrat protocol may be a problem for monitoring and measurement of environmental impacts. This may be serious for groups such as snakes and other larger reptiles, for which substantial decline has been suggested following spread of cane toads (Covacevich and Archer 1975; Burnett 1997; Catling *et al.* 1999). This study suggests that our quadrat sampling protocol will need to be modified to include more effort and/or different sampling techniques for such species. This modification should include greater effort devoted to searching for such species and/or the use of traps more specifically designed to sample the currently under-represented taxa.

The low level of correlation between trench captures in 1994 and 1999 suggests that a range of factors may make samples from trenches highly variable. In this case, some of the variation may be due to different locations and habitats being sampled (although there was substantial overlap in both of these), some seasonal influence (again, although there was substantial overlap), and possibly differences between years in animal populations (which may contribute some explanation of the extraordinary difference in rodent captures between the two trenching events). However, as well as these factors, differences in sampling regime and differences in trench construction may also have contributed to the contrasts in species composition and relative "abundance" between the two samples. The 1999 survey sampled relatively small sections of the trench intensively, and generally relatively soon (<5 days) after the trench was established. In contrast, the 1994 sampling was far less intensive and, in many cases, searches were made at long intervals and long after the trench had been opened. A biased selection of species may have escaped the trench or been eaten during such relatively long intervals. With regard to predation, it is notable that there were many reports in the 1994 survey of cat, dog and goanna tracks in the trench, and records of raptors patrolling along the trench: there was little sign of this in the 1999 sampling, almost certainly because the trench was being constructed and filled far more rapidly, and inspected more frequently, than in 1994.

On a broader scale, marked differences in habitats, sampling methods and construction protocol influenced the contrast between the results from this study and those of the two pipeline studies in New South Wales (Ayers and Wallace 1997; Faulkner 1999), although there are some notable similarities in all studies. The most marked contrasts are that our study had a very low representation of frogs (which is a simple seasonal factor), and a substantially lower mortality rate. To some extent, the latter may also be a seasonal factor, as the timing of pipeline construction in our study coincided with the season of least stressful climate.

Table 3. Summary of measures which reduce capture and mortality of wildlife during trench construction.

type of measure	recommended procedure	explanation
construction operational	• undertake operations in the most benign season	• wildlife mortality is likely to be highest in hot (or very cold) weather; • wildlife activity may also be higher in warm weather than cool weather, so capture rates then would be greater
	• interrupt trench with frequent "escape ramps" for captured wildlife	• exit points from the trench will enable trapped animals to leave the trench: sloping ramps away from the trench every 200 – 500 m should be sufficient for most species
	• minimise the time the trench is opened, through careful planning of construction and pipe laying	• fewest animals will be trapped if pipe laying (and immediately thereafter trench filling) occurs within 24 hr of trench opening
	• site pipeline route to avoid areas of exceptional conservation values (e.g. remnant bushland, essential habitat for threatened species, etc.)	
inspection	• ensure that trenches are inspected frequently	• mortality is likely to be minimised if all trench sections are checked at early morning and late afternoon

This influence of seasonality on mortality patterns may provide one mechanism for minimising the impact of pipeline construction. Our results failed to reveal any clear pattern connecting mortality with either trench age or frequency of trench inspection. These (non)results are a little surprising, and may be explained by a) the relatively narrow range of both of these variables in this study, b) the imprecision in our estimation of these ages in this study, c) the possibility that build-up in numbers of captured animals with increasing trench age is compensated for by an increased likelihood of dead animals being consumed or taken away by scavengers, and/or d) unavoidable error in relating the location of animals found in the trench with their point of entry. We strongly suspect that we would have had substantially higher mortality rates if the period between our inspections was increased beyond the maximum we used. Variation in trench construction techniques may also substantially affect capture and mortality rates. Narrow deep trenches may be relatively cool and shady, but may make escape less likely. Other procedures which will decrease mortality include rapid construction linked with rapid filling of trenches (such that only small extents of trench are open at any time) and the provision of escape ramps at frequent intervals (e.g. every 200 to 500 m). A summary of these mitigation measures is presented in Table 3. Generally similar measures were proposed by Ayers and Wallce (1997) and Faulkner (1999). Faulkner (1999) recommended that such measures be explicitly incorporated into the Environmental Management Plan or Environmental Impact Statement governing the construction project. These measures should also be included within an environmental code of practice by the pipeline construction industry.

Somewhat conversely to impact minimisation, in some cases it may be most productive (in terms of gathering information on wildlife distribution and abundance, and especially for species which may otherwise be difficult to detect), to use sampling and construction techniques which maximise captures. This study suggests that capture rate, at least for nocturnal animals, is largely a function of frequency of inspection (at least, over the limited range of inspection intervals that we used).

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